# AGC METHOD AND CIRCUIT FOR DIGITAL RADIO RECEIVER

## BACKGROUND OF THE INVENTION

The present invention relates to a digital radio receiver, or in particular to an AGC (automatic gain control) method and an AGC circuit for controlling

5  the level of the received signal.

The level of the signal received by the receiver used for digital radio communication changes with the propagation characteristics.  An AGC circuit is required, therefore, for controlling the input

10  signal of a demodulator at a constant level regardless of a change in the input signal level.  Generally, an AGC circuit uses an amplifier, and the level of the received signal is regulated by changing the gain of the amplifier for amplifying the input signal.  A

15  method is widely known, in which a RSSI (received signal strength indicator) signal obtained by logarithmic amplification and envelope detection of the input received signal is used to control the gain of the amplifier.

20  An AGC method using an interval average of the RSSI signal will be explained with reference to Fig. 1.

Fig. 1 is a block diagram showing an example configuration of a conventional AGC circuit for

25  performing the control operation using the interval

average of the RSSI signal.  In Fig. 1, reference
numeral 101 designates an input terminal, numeral 102
an amplifier (for example, a variable gain amplifier),
numeral 103 a RSSI circuit, numeral 104 an A/D (analog-

5  to-digital) converter, numeral 105 an interval average
calculation circuit, numeral 110 a gain control unit,
numeral 111 a D/A (digital-to-analog) converter and
numeral 112 a demodulation circuit.

In Fig. 1, the signal received by the digital

10  radio receiver is applied through the input terminal
101 to the amplifier 102 and the RSSI circuit 103.  The
RSSI circuit 103 logarithmically amplifies the received
signal applied thereto from the input terminal 101, and
after envelope detection, outputs a RSSI signal.  The

15  RSSI output signal, as the result of logarithmic
amplification and envelope detection, is proportional
to the logarithm of the received signal level.

Fig. 2 is a block diagram showing in detail
an example of the RSSI circuit 103.  In Fig. 1, the

20  received signal from the input terminal 101 is applied
to an envelope detector 103a, and the output signal of
the envelope detector 103a is applied to a logarithmic
amplifier 103b, where it is logarithmically amplified.
The signal thus logarithmically amplified is further

25  applied to a low-pass filter (LPF) 103c for removing
the amplitude variations caused by modulation, and
outputted as a RSSI signal.  The low-pass filter is
intended to remove the amplitude variations due to the

modulation and desirably has a time constant of not

less than 2 symbols but not more than about 10 symbols.

In the description of embodiments that follows, the

time constant of the low-pass filter is assumed to be 2

5   symbols, for example.

Fig. 3 is a characteristic diagram showing

the voltage of the RSSI output signal of the RSSI

circuit versus the power of the received signal. The

received signal power on the abscissa is shown by

10  logarithmic scale, and therefore the output voltage of

the RSSI signal is proportional to the logarithm of the

received signal power.

The RSSI output signal of the RSSI circuit

103 is converted into a digital signal in the A/D

15  converter 104, and applied to the interval average

calculation circuit 105. The RSSI signal, that has

passed through the low-pass filter 103c having a time

constant of 2 symbols, for example, is sampled by the

A/D converter 104 for every 2 symbols. The RSSI signal

20  sampled and converted into a digital signal in this way

is hereinafter called an instantaneous value r of the

RSSI signal. In the following explanation, the signal

processing from the A/D converter 104 to the D/A

converter 111 is performed by the digital signal

25  processing, and the period of the operation clock

signal (period of the operation clock timing) of this

digital signal processing is two symbols. In the radio

communication system, signal is generally transmitted

and received on a frame unit basis of a predetermined data length. For example, when one frame is 40 msec and formed by 192 symbols, 2 symbols has a period of about 0.42msec.

5          The interval average calculation circuit 105 calculates the input RSSI signal (the instantaneous value r of the RSSI signal) with a time constant (time tX) of a period longer than several tens of symbols, and applies the interval average value rX of the

10    instantaneous values r of the RSSI signal providing the result of calculations to the gain control unit 110.

In the gain control unit 110, a control signal g for controlling the gain of the amplifier 102 is produced based on the input interval average value

15    rX, and after being converted into an analog signal by the D/A converter 111, applied to the amplifier 102.

In the amplifier 102, the received signal input from the input terminal 101 is amplified with a gain corresponding to the control signal g input

20    through the D/A converter 111, and the amplified signal is applied to the demodulation circuit 112.

The signal output from the amplifier 102 is a modulated wave, and this modulated wave signal is subjected to frequency change, detection and signal

25    point determination in the demodulation circuit 112 thereby to retrieve the information contained in the modulated wave.

The signal received by the digital radio

receiver is segmented for each frame, and the frame is roughly configured of a control information section containing the sync data and a data section. For example, Fig. 4 is a diagram for explaining the frame

5    structure of a sync burst frame according to ARIB STD-T61 providing a standard specification of FDMA (frequency division multiple access). Fig. 5 is a diagram for explaining the frame structure of a traffic channel according to the same specification.

10        Figs. 4 and 5, reference characters "LP+R" designates a linearizer preamble and ramp-up section, "Pb" a preamble section, "RI" a communication information channel section, "SW" a sync word pattern section, "PI" a parameter information channel section, "G" a

15   guard time section, "Tch a traffic channel section, and "UD" an undefined section. The numeral values described under the respective symbols represent the number of bits for the areas thereof, respectively. The sections "LP+R" and "Pb" make up a control informa-

20   tion section, and the remainders constitute a data section. The AGC operation is performed using a part of "LP+R" or "Pb".

        In the specification of Fig. 4, the modulation scheme is the $\pi/4$ shift QPSK (quaternary phase

25   shift keying), a modulation rate of 4.8 kbaud, a frame length of 40 msec, and 192 symbols (384 bits; 1 symbol = 2 bits) per frame.

        Fig. 6 is a diagram showing an example of a

transmission pattern. In Fig. 6, "$SB_0$" and "$SB_1$" are frames of the sync burst shown in Fig. 4, and "TchN" (N: natural number) a frame of the traffic channel shown in Fig. 5. In the example of Fig. 6, after two

5   frames of sync burst are transmitted, N+1 frames of the traffic channel are transmitted. An explanation will be given below of the case in which the signal of the transmission pattern shown in Fig. 6 is received by the receiver.

10      Figs. 7A to 7E are time charts showing the signal waveforms of the various parts for explaining the operation of the AGC circuit of Fig. 1. Specifically, these time charts represent the signal waveforms of the respective parts produced by the AGC operation

15   performed with the interval average value rX of the RSSI signal using the AGC circuit shown in the block diagram of Fig. 1 in the case where the signals of frames n to n+k (n, k: integer) are applied to the receiver. Fig. 7A shows a received signal, Fig. 7B an

20   instantaneous value r of the RSSI signal, Fig. 7C an interval average value rX of the RSSI signal, Fig. 7D a control signal g, and Fig. 7E an input signal to the demodulation circuit 112. In Figs. 7A and 7E, the actual signal is a modulate wave and only the envelope

25   is plotted by solid line while the modulated wave signal is not shown.

        The AGC operation using the interval average value rX of the RSSI signal will be explained with

reference to Figs. 7A to 7E.

As shown in Fig. 7A, the received signal of frames n to n+k is input within the time of frames n-1 to n+k+1. In the frames n-1 and n+k+1 where the

5   received signal is not input, therefore, the instantaneous value r of the RSSI signal assumes a minimum level, while the instantaneous value r of the RSSI signal assumes the level R shown in Fig. 7B in the frames n to n+k where the received signal is input.

10  The most simple frame structure is configured of preamble and data. The frame n is configured of a preamble and data as shown in Fig. 8A, and the frames n+1 to n+k may each be configured of data only as shown in Fig. 8B. A specific example of the preamble and the

15  data is Nf = 192 symbols and Np = 44 symbols.

As shown in Fig. 7C, the interval average calculation circuit 105 determines the interval average value of the instantaneous values r (i.e. the average value of the instantaneous values r of the SSI signal

20  during the time length tX) of the RSSI signal with a long time constant of not less than several tens of symbols, and therefore the interval average value rX takes a time for rise. The interval average is defined as an average value of the instantaneous values during

25  a predetermined time length tX before the ith instantaneous value ri (i: arbitrary natural number) detected, and is determined at each detection time point (for every two symbols in the case under

consideration) of the instantaneous value r.

Thus, as shown in Fig. 7D, the control signal
g is gradually attenuated after assuming a maximum gain
at the head of the frame n.  As a result, as shown in
5  Fig. 7E, the signal applied to the demodulation circuit
112 becomes an excessive input in the head portion of
the frame n.

## SUMMARY OF THE INVENTION

For the reason described above, the AGC
10  operation is required to be performed quickly at the
rise time of the received signal level.

Specifically, in the case where the received
signal is continuously applied, as shown in the portion
following to the heads portion in the frame n and the
15  frames n+1 to n+k in Figs. 7C, 7D, 7E, the AGC opera-
tion is required to be performed slowly based on the
interval average value rX of the RSSI signal in order
to prevent the suppression of the amplitude component
contained in the modulated wave.  At the rise time of
20  the received signal level, however, a slow pull-in of
the AGC operation would make it impossible to follow a
sharp rise of the level, and therefore the AGC opera-
tion is required to be pulled in quickly.

The RSSI signal is proportional to the
25  logarithm of the received signal level, and therefore
by performing the AGC operation using an instantaneous
value or a short interval average value (a time

constant not more than several symbols, for example) of the RSSI signal, a sharp level change of the received signal can be followed.  In the case where a modulation scheme such as PSK (phase shift keying) or QAM

5 (quadrature amplitude modulation) having no constant amplitude, however, the amplitude component of the modulation is contained in the RSSI signal.  An AGC operation performed using the instantaneous value or the short interval average value of the RSSI signal,

10 therefore, would suppress the amplitude component due to the modulation.  In order to prevent this suppression, the AGC operation is required to be performed using a long interval average (a time constant of not less than the periods of several tens of symbols).

15 In the communication between a fixed station and a base station, the AGC operation is required since the propagation characteristics changes when a vehicle etc. moves within the propagation path therebetween.

Further, like the radio communications for

20 business or disaster control, in the communication between a mobile station and a base station, the propagation characteristics and the received signal level change not only while the mobile station is moving, but also after movement of the mobile station.

25 Thus, the AGC operation is required each time of arrival of the received signal.  Also, the received signal may be as short as only one frame.  In the radio communication for disaster prevention, even the signal

of one frame is important and required to be received
positively. Thus, the AGC operation is required which
can detect the first frame of the received signal
without fail.

5          The object of the present invention is to
obviate the disadvantages of the prior art that a sharp
level rise of the received signal cannot be followed
and to provide an AGC method and an AGC circuit capable
of optimum AGC operation both when continuously receiv-
10  ing the received signal and at the rise time of the
received signal.

        In order to achieve the object described
above, the AGC method according to this invention uses
an AGC circuit of the receiver for the digital radio
15  communication and is intended to detect the envelope of
the received signal (RSSI signal, for example) and upon
detection of a rise of the received signal, perform the
AGC operation rapidly.

        Specifically, according to a first aspect of
20  the invention, there is provided an AGC (automatic gain
control) method for a digital radio receiver, wherein
the gain of an amplifier is automatically changed in
accordance with the level of the signal received by the
digital radio receiver thereby to control the gain, the
25  method comprising the steps of:

        (a) detecting an instantaneous value of the
envelope of the input received signal sequentially at
predetermined time intervals;

(b) determining the first interval average value providing an average value of the instantaneous values for a predetermined time length before the instantaneous value detected;

5      (c) determining a difference value between the  instantaneous value and the first interval average value;

(d) in the case where the difference value exceeds a predetermined threshold value, setting, upon

10  the lapse of a third predetermined time length from the time when the difference value exceeds the predetermined threshold value, the gain of the amplifier at a value corresponding to the instantaneous value as of the lapse of the third predetermined time length; and

15      (e) maintaining, during a fourth predetermined time length following the lapse of the third predetermined time length, the gain corresponding to the instantaneous value as of the lapse of the first predetermine time, and after the lapse of the fourth

20  predetermined time length, setting, at each time point of detecting the instantaneous value, the gain to a value corresponding to a first interval average providing an average of the instantaneous values during a predetermined time length before the instantaneous

25  value.

According to another aspect of the invention, there is provided an AGC (automatic gain control) method for a digital radio receiver, wherein the gain

of an amplifier is automatically changed in accordance with the level of the signal received by the digital radio receiver thereby to control the gain, the method comprising the steps of:

5      (a) detecting the instantaneous value of the envelope of the input received signal sequentially at predetermined time intervals;

(b) determining the first interval average value providing an average value of the instantaneous
10   values for a first predetermined time length before the instantaneous value detected, and determining the second interval average providing an average of the instantaneous values during a second predetermined time length shorter than the first predetermined time length
15   before the  instantaneous value detected;

(c) determining the difference value between the  instantaneous value and the first interval average value;

(d) in the case where the difference exceeds
20   a predetermined threshold value, setting the gain of an amplifier at a value corresponding to the second interval average value during the second predetermined time length before the instantaneous value as of the lapse of the third predetermined time length from the
25   time when the difference exceeds the predetermined threshold value; and

(e) maintaining, during a fourth predeter-mined time length following the lapse of the third

predetermined time length, the gain set in step (d),
and upon the lapse of the fourth predetermined time
length, setting, for each detection time point of the
instantaneous value, the gain to a value corresponding

5 to the first interval average value during the first
predetermined time length before the instantaneous
value.

In the AGC method according to this inven-
tion, the time before the lapse of the predetermined

10 time after the difference value exceeds the predeter-
mined threshold value following the input of the
received signal is sufficiently long to converge the
second internal (short interval) average value.

Further, the time before the lapse of the

15 third predetermined time length and the fourth
predetermined time length after the difference value
exceeds the predetermined threshold value following the
input of the received signal is sufficiently long to
converge the first interval (long interval) average

20 value.

Furthermore, in the AGC method according to
this invention, the RSSI signal is detected, and the
instantaneous value of the detected RSSI signal is
assumed to be the instantaneous value r of the envelope

25 of the received signal.

According to still another aspect of the
invention, there is provided an AGC (automatic gain
control) circuit comprising an amplifier supplied with

the signal received by a digital radio receiver, the amplifier controlling the gain by changing the gain automatically in accordance with the signal level of the input received signal, the circuit further

5   comprising:

a detection unit for detecting and outputting the instantaneous value of the envelope of the input received signal sequentially at predetermined time intervals;

10   a first interval average value calculation unit connected to the detection unit for determining the first interval average value providing the average value of the instantaneous values during a first predetermined time length before the instantaneous

15   value detected by the detection unit;

a second interval average value calculation unit connected to the detection unit for determining the  second interval average value providing the average of the instantaneous values during a second

20   predetermined time length shorter than the first predetermined time length before the instantaneous value detected by the detection unit;

a difference calculation unit connected to the detection unit and the first interval average value

25   calculation unit for determining the difference between the detected instantaneous value and the first interval average value;

a switching unit for selectively outputting

one of the first interval average value determined by
the first interval average value calculation unit and
the second interval average value determined by the
second interval average value calculation unit;

5          a switching control unit for controlling the
switching unit; and

           a gain control unit connected to the output
of the switching unit for outputting a signal for
changing the gain of the amplifier in accordance with
10   the output of the switching unit;

           wherein in the case where the difference
value calculated by the difference calculation unit
exceeds a predetermined threshold value, the switching
control unit controls the switching unit in such a
15   manner that the second interval average value during
the second predetermined time length before the instan-
taneous value upon the lapse of the third predetermined
time length is applied from the second interval average
value calculation unit to the gain control unit upon
20   the lapse of the third predetermined time length after
the difference exceeds the predetermined threshold
value;

           wherein the switching unit is controlled in
such a manner that the second interval average value
25   during the second predetermined time length before the
instantaneous value upon the lapse of the third
predetermined time length continues to be applied to
the gain control unit during the time before the lapse

of the fourth predetermined time length following the
lapse of the third predetermined time length; and

wherein upon the lapse of the fourth
predetermined time length, the switching unit is
5   controlled in such a manner that the first interval
average value determined by the first interval average
value calculation unit during the predetermined time
length before the instantaneous value is output to the
gain control unit at each time point of detecting the
10  instantaneous value.

According to the invention having this
configuration, the AGC operation is pulled in rapidly
at the rise time of the received signal level by
detecting the received signal level.  Also, as long as
15  the received signal is received continuously, the AGC
operation is performed at low speed with the long
interval average of the RSSI signal in order to prevent
the suppression of the amplitude component contained in
the modulated wave.


20  BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a block diagram showing an example
of a configuration of a conventional AGC circuit.

Fig. 2 is a block diagram showing an example
of a configuration of a RSSI circuit shown in Fig. 1.

25      Fig. 3 is a characteristic diagram showing
the voltage of the output RSSI signal versus the power
of the received signal in the RSSI circuit shown in

Fig. 2.

Fig. 4 is a diagram for explaining the frame structure of an example of a sync burst frame.

Fig. 5 is a diagram for explaining the frame structure of an example of a traffic channel.

Fig. 6 is a diagram showing an example of a frame transmission pattern.

Figs. 7A to 7E are time charts showing the signal waveforms of various parts for explaining the operation of the AGC circuit shown in Fig. 1.

Figs. 8A and 8B are diagrams showing an example of a frame structure of signal.

Fig. 9 is a block diagram showing an example of a configuration of the AGC circuit according to an embodiment of the invention.

Fig. 10 is a block diagram showing an example of a configuration of the long interval average calculation circuit.

Figs. 11A to 11G are time charts showing the signal waveforms of the various parts for explaining the AGC circuit shown in Fig. 9.

Figs. 12A to 12J are time charts showing the signal waveforms of the various parts for explaining the AGC circuit shown in Fig. 9.

Fig. 13 is a block diagram showing a configuration of an AGC circuit according to another embodiment of the invention.

Fig. 14 is a flowchart showing the operation

of processing a microcomputer according to the embodi-
ment shown in Fig. 13.


## DESCRIPTION OF THE EMBODIMENTS

An AGC circuit according to an embodiment of
5   the invention will be explained below with reference to
the accompanying drawings.

Fig. 9 is a block diagram showing an example
of a configuration of the AGC circuit for implementing
the AGC method according to this invention.  In Fig. 9,
10  the component elements having the same functions as
those described in Fig. 1 are designated by the same
reference numerals, respectively.  Reference numeral
115 designates a long interval average calculation
circuit, numeral 116 a short interval average calcula-
15  tion circuit, numeral 117 an adder, numeral 119 a
switch (SW) for selectively applying the output of the
long interval average calculation circuit 115 or the
output of the short interval average calculation
circuit 116 to a gain control unit 110, and numeral 118
20  a switching control unit for operating the switch 119
in accordance with the output of the adder 117.  Now,
the control operation of the AGC circuit according to
this embodiment will be explained with reference to
Fig. 9 and other figures.  The signal in the present
25  invention may have either a frame structure as shown in
Figs. 4 to 6, for example, or a simple frame structure
as shown in Figs. 8A, 8B.

In Fig. 9, the signal received by the
receiver is applied through an input terminal 101 to an
amplifier 102 and a RSSI circuit 103.  The functions of
the demodulation circuit 112 supplied with the output
5  of the amplifier 102 for performing the demodulation,
and the functions of the RSSI circuit 103, the A/D
converter 104, the gain control unit 110 and the D/A
converter 111 are identical to those of the prior art
and therefore will not be explained.

10      The instantaneous value of the RSSI signal r
converted into a digital signal in the A/D converter
104 is applied to the long interval average calculation
circuit 115, the short interval average calculation
circuit 116 and the input terminal on the positive
15  (plus) side of the adder 117.

In the long interval average calculation
circuit 115, like in the interval average calculation
circuit 105 shown in Fig. 1, the instantaneous value r
is calculated with a time constant longer than several
20  tens of symbols at each time point when the RSSI signal
(the instantaneous value r of the RSSI signal) input
from the A/D converter 104 is detected, thereby
determining and outputting the long interval average
value $r_L$ of the instantaneous values r of the RSSI
25  signal (i.e. the average value of the instantaneous
values r of the RSSI signal during the time length $t_L$).
More specifically, the long interval average calcula-
tion circuit 115 calculates, each time the ith

instantaneous value ri (i: arbitrary natural number) is input, a long interval average value $r_{Li}$ which is the average value of the instantaneous values r during the predetermined time length $t_L$ before the instantaneous

5   value ri.

The long interval average value $r_L$ of the instantaneous values of the RSSI signal r output from the long interval average calculation circuit 115 is applied to the terminal a of the switch 119 on the one

10  hand and to the negative (minus) input terminal of the adder 117 at the same time.

On the other hand, the short interval average calculation circuit 116 calculates the short interval average value $r_s$ of the RSSI signal r based on the

15  instantaneous value r of the RSSI signal input from the A/D converter 104 is calculated with a time constant as short as several symbols at each time point when the instantaneous value r is detected.  Thus, the short interval average value $r_s$ of the instantaneous values r

20  of the RSSI signal (i.e. the average value of the instantaneous values r of the RSSI signal during the time length $t_s$) is determined and applied to the terminal b of the switch 119.  More specifically, the short interval average calculation circuit 116

25  calculates, each time the ith instantaneous value ri is applied thereto, a short interval average value $r_{si}$ which is the average value of the instantaneous values r during the predetermined time length $t_s$ before the

instantaneous value ri.

Fig. 10 is a block diagram showing an example of a configuration of the long interval average calculation circuit 115 including multipliers 120, 122, an adder 121 and a delay element 123. In Fig. 10, reference character r(m) designates a RSSI signal output from the A/D converter 104, which, as described above, is a signal sampled for each two symbols, for example. Character $r_L(m)$ designates a long interval average value $r_L$ calculated, and character m designates a sample number p thereof which is assumed to be a constant of 0.03. Fig. 10 can be expressed as an equation below, in which the output $r_L(m)$ is the sum of r(m) multiplied by p plus the smoothed output $r_L(m-1)$ two symbols before, multiplied by (1-p). The delay element 123 is for delaying one sample, i.e. two symbols.

$$r_L(m) = p \times r(m) + (1-p)r_L(m-1)$$

In the case where the sampling period of the RSSI signal is two symbols and p is 0.03, the long interval average value converges to about 80 % for 120 symbols (60 samples).

The short interval average calculation circuit 116 has a similar configuration to the long interval average calculation circuit 115 shown in Fig. 10, where p is given as 0.3. The output rs(m) of the short interval average calculation circuit is applied to the terminal b of the switch 119, which output rs(m)

converges to about 75 % for eight symbols (4 samples).

The switch 119 connects the terminal d selectively to one of the terminals a, b, c in response to a signal from the switching control unit 118. When the terminal d is connected to terminal a, the long interval average value $r_L$ input from the long interval average calculation circuit 115 is applied to the gain control unit 110. When the terminal d is connected to the terminal b, on the other hand, the short interval average value $r_s$ input from the short interval average calculation circuit 116 is applied to the gain control unit 110. When the terminal d is connected to terminal c, the gain control unit 110 holds the output immediately before the particular connection. The terminal c of the switch 119 is supplied with no signal.

Specifically, the gain control unit 110 includes a sample hold unit, for example, for holding the immediately preceding input signal (the short interval average value $r_s$, for example) while no signal is input thereto.

In the adder (difference calculation unit) 117, the difference value $\Delta ri$ ($\Delta ri = ri - r_{Li}$) between the ith instantaneous value ri of the RSSI signal input from the A/D converter 104 and the long interval average value $r_{Li}$ (i.e. the average value of the instantaneous values during a predetermined time length $t_L$ before the instantaneous value ri) of the RSSI signal input from the long interval average calculation

circuit 115 is calculated, and the difference value $\Delta r_i$ thus calculated is applied to the switching control unit 118.

The switching control unit 118 compares the difference value $\Delta r_i$ with a preset threshold value $\Delta r_{th}$, and by performing the following determining operations (1), (2) and (3), changes the connection of the switch 119 in accordance with the determining operations. In this case, the AGC circuit performs the control operation with clock timings shown in Fig. 12J. In the case where the AGC circuit is in standby state awaiting the arrival of a received signal input, however, the switch 119 normally connects the terminal a to the terminal d.

Determining operation (1): Before a time point where the difference value $\Delta r_i$ exceeds the threshold value $\Delta r_{th}$, the terminal a of the switch 11 is connected to the terminal d, and the long interval average value $r_{Li}$ output from the long interval average calculation circuit 115 is applied to the gain control unit 110 (low-speed process).

Upon lapse of a predetermined time $t_1$ from the time point when the difference value $\Delta r_i$ has exceeded the threshold value $\Delta r_{th}$, the terminal b of the switch 119 is connected to the terminal d, the short interval average value $r_{si}$ output from the short interval average circuit 116 is applied to the gain control unit 110, and the state of the gain control unit 110 is preset by

the value $r_{si}$ (start of high-speed process).

Determining operation (2): At the next operation clock timing after presetting the state of the gain control unit 110 by the short interval average

5 value $r_{si}$, the terminal c of the switch 119 is connected to the terminal d, and the state of the gain control unit 110 is held (high-speed process).

Determining operation (3): Upon lapse of the predetermined time $t_1 + t_2$ from the time point when the

10 difference value $\Delta ri$ has exceeded the threshold value $\Delta r_{th}$, the terminal a of the switch 119 is connected to the terminal d, and the long interval average value $r_L$ output from the long interval average calculation circuit 115 is applied to the gain control unit 110

15 (low-speed process). In this case, the predetermined time $t_1 + t_2$ is a time period during which the long interval average calculation circuit 115 starts calculation, then converges the calculation and the long interval average value $r_L$ converges.

20 The long interval average calculation circuit 115 and the short interval average calculation circuit 16 always calculate and output the long interval average value $r_L$ and the short interval average value $r_s$, respectively, by operating in response to each

25 instantaneous value r of the RSSI signal input at each operation clock timing. When the long interval average value $r_L$ or the short interval average value $r_s$ is applied to the gain control unit 110 from the switch

119, the gain control unit 110 calculates and outputs the control signal g based on the value $r_L$ or $r_s$ applied thereto. In the case where the terminals c and d of the switch 119 are connected to each other, on the

5 other hand, the immediately preceding calculated value of the control signal g is held and output. The control signal g output from the gain control unit 110 is converted into an analog signal by the D/A converter 111, and applied to the control terminal of the

10 amplifier 102 thereby to control the gain of the amplifier 102 by a well-known method.

The amplifier 102 changes the gain in accordance with the value of the control signal input thereto from the D/A converter 111, amplifies the received

15 signal input from the input terminal 101 and applies the amplified signal to the demodulation circuit 112.

Figs. 11A to 11G, like Figs. 7A to 7E, are time charts showing signal waveforms of various parts for explaining the operation of the AGC circuit in the

20 case where the AGC operation is performed by the AGC circuit shown in Fig. 9 for the signal of frame n to frame n+k (n, k: integer) received by the receiver. Figs. 12A to 12J are time charts plotted in enlarged form for the time length of the several tens of symbols

25 from the head of the frame n. The AGC circuit shown in Fig. 9 is operated in synchronous with the operation clock signal shown in Fig. 12J. The operation of the AGC circuit shown in Fig. 9 will be explained with

reference to Figs. 11A to 11G and Figs. 12A to 12I. In Figs. 11A to 11G and Figs. 12A to 12I, Figs. 11A, 12A show a received signal, Figs. 11B, 12B an instantaneous value r of the RSSI signal, Figs. 11C, 12C a long

5    interval average value $r_L$ of the RSSI signal, Figs. 11D, 12D a short interval average value $r_s$ of the RSSI signal, Figs. 11E, 12E a difference value $\Delta r$ ($\Delta r = r - r_L$), Figs. 11F, 12F a control signal g, Figs. 11G, 12G an input signal of the demodulation circuit 112, Fig.

10   12H the manner in which the switch 119 is controlled by the switching control unit 18, and Fig. 12I an input signal of the gain control unit 110. In Figs. 11A, 12A, 11G, 12G, the actual signal is a modulated wave, and only the envelope is plotted in solid line while

15   the modulated wave signal is not shown.

In Figs. 11A to 11G and Figs. 12A to 12I, the signal is received from the frame n to frame n+k. As shown in Figs. 11B, 12B, the instantaneous value r of the RSSI signal assumes a level R for the frame n to

20   frame n+k, while the instantaneous value r assumes a minimum level R0 for the other frames. In Figs. 12A to 12I, the signal is assumed to be received even for the frame n+k+2.

The long interval average value $r_L$ of the RSSI

25   signal is calculated by the long interval average calculation circuit 115 with a time constant of several tens of symbols, as shown in Figs. 11C, 12C, and there-fore the time corresponding to several tens of symbols

is consumed for rise.

The difference value $\Delta r$ (= $r - r_L$) between the instantaneous value $r$ of the RSSI signal and the long interval average value $r_L$, as shown in Fig. 11E, is

5 the difference between two signals of different rise time. Therefore, a positive value is exhibited at the rise time and a negative value at the fall time of the received signal level.

The AGC circuit shown in Fig. 9 detects the

10 rise of the received signal level and selects an optimum AGC control method utilizing the character- istics of the difference value $\Delta r$ described above. Specifically, when the received signal is received continuously, the AGC operation is performed with the

15 long interval average value $r_L$ of the RSSI signal, while at the rise time of the received signal, the AGC opera- tion is performed with the short interval average value $r_s$ of the RSSI signal or the instantaneous value of the RSSI signal.

20 The AGC operation will be described in detail with reference to Figs. 12A to 12I. The power supply (not shown) for the AGC circuit is turn on and the RSSI signal begins to be received. The AGC operation is performed with the long interval average value $r_L$ until

25 immediately after the time point 400 (interval 401) when the signal is received in the frame n. As described above, the long interval average value $r_{Li}$ at the time point when the ith instantaneous value $ri$ (i:

arbitrary natural number) is input is an average value of the instantaneous values r during a predetermined time length $t_L$ before the instantaneous value ri. Therefore, the long interval average value $r_L$ before the time point 400 when the frame n is received is R0, and gradually increases after the time point 400 (see Fig. 12C). Thus, the difference value $\Delta r$ (= $r - r_L$) remains 0 until the time point 400 when the frame n is received, and subsequently gradually increases (see Fig. 12E).

After the power for the AGC circuit is turned on, until the difference value $\Delta r$ exceeds the preset threshold value $\Delta r_{th}$ (time point 402) and further a specified time $t_1$ elapses at time point 403, the terminal d remains connected to the terminal a of the switch 119, and the AGC operation is performed by the long interval average value $r_L$ of the RSSI signal. Thus, the input signal of the gain control unit 110, as shown in Fig. 12I, gradually increases from time point 400 to time point 403 in accordance with the long interval average value $r_L$. Therefore, the signal input to the demodulation circuit 112 changes in the manner shown in Fig. 12G.

At the time point 403 upon the lapse of a specified time $t_1$ from the time point 402 when the difference value $\Delta r$ has exceeded the preset threshold value $\Delta r_{th}$, the terminal d of the switch 119 is turned to the terminal b, and the value of the control signal

g is preset to a value based on the short interval

average value $r_s$. The value of the control signal g,

after being thus preset, is fixed (the terminal d of

the switch 119 is connected to the terminal c) during

5 the specified time $t_2$ (until the time point 404 when the

AGC operation is restarted by the long interval average

value of the RSSI signal in Fig. 12G), and at time

point 404, the AGC operation by the long interval

average value $r_L$ is restored (the terminal d of the

10 switch 119 is connected to the terminal a).

The time until the lapse of the predetermined

time $t_1$ from the time point when the difference value

$\Delta r$ has exceeded a predetermined threshold value $\Delta r_{th}$

after the received signal is input is a sufficient

15 length of time for the short interval average value $r_s$

to converge.

Further, the time length until the lapse of

the predetermined time $t_1$ and the predetermined time $t_2$

from the time point when the difference value $\Delta r$ has

20 exceeded the predetermined threshold value $\Delta r_{th}$ after

the received signal input is sufficiently long for the

long interval average value $r_L$ to converge.

In this manner, the predetermined time $t_1$ is a

time sufficient for the short interval average value $r_s$

25 to converge, and the predetermined time $t_2$ is a time

sufficient for the long interval average value $r_L$ to

converge.

In this way, at the time point 403 when the

difference value $\Delta r$ has exceeded the predetermined
value and the short interval average value rs has
settled during the interval containing no information
after arrival of the received signal of the frame n,

5   the AGC operation is performed by presetting the
control signal g based on the short interval average
value rs, after which the AGC operation is switched to
the one based on the long interval average $r_L$ at the
time point 404 after the long interval average value $r_L$

10  is settled.

As a result, at the rise time of the received
signal level, the AGC operation is performed quickly
during the interval containing no information in the
frame. As long as the received signal is continuously

15  received, on the other hand, the AGC operation is
performed at low speed with the long interval average
of the RSSI signal in order to prevent the suppression
of the amplitude component contained in the modulated
wave. In this way, the proper AGC method can be

20  selected in accordance with the receiving condition.

Now, with reference to Figs. 12A to 12J, an
explanation will be given of the case in which after
receiving the signal in the frame n+k, no signal is
received in the next frame n+k+1, and the signal is

25  received in the second next frame n+k+2. In this case,
during the time from the time point 405 when the frame
n ends to the time point 408 associated with the frame
n+k+2 (i.e. the time point when the difference value $\Delta r$

exceeds the threshold value $\Delta r_{th}$ (time point 407) and further upon the lapse of the specified time $t_1$), the terminal d of the switch 119 remains connected to the terminal a. At time point 408, the terminal d of the

5 switch 119 is turned to the terminal b, and the value of the control signal g is preset to a value based on the short interval average value $r_s$.

The required information can be received efficiently by performing this high-speed process

10 before the end of the interval of the data uniquely specified for a communication system containing no transmission information in the received frame (the interval containing no information in the received frames (say, LP+R, Pb of Figs. 4 and 5)) after the end

15 of the AGC operation (after the convergence of the amplitude of the input signal (Fig. 12G) of the demodulation circuit 112). Specifically, the AGC operation and the high-speed sync process are performed during the interval containing no information in the

20 frame n in Figs. 12A to 12I. This requires that the time constant for determining the short interval average value $r_s$ for high-speed sync process (the time length $t_s$ to determine the average value) is set to a time shorter than the time length of the interval

25 containing no information in the received frame, less the time required for the AGC operation (the time length from the time point when the control signal g is preset to the time point when the amplitude of the

input signal of the demodulation circuit 112 (Fig. 12G)
converges), and also less the time required for the
high-speed sync process.  This example will be further
explained with reference to Fig. 4.

5          When receiving the frame of the sync burst
shown in Fig. 4, the linearizer preamble line-up (LR+R)
and the preamble (Pb) are received at the head of the
frame.

          According to the specification shown in Fig.
10  4, the linearizer preamble line-up (LR+R) may or may
not be output from the transmitter, and therefore it is
not determined whether it is contained in the received
signal or not.  Also, the preamble (Pb) contains 44
symbols of the fixed pattern.  The information to be
15  transmitted is not contained in (LR+R) and (Pb), and
therefore only the preamble (Pb) may be received.
Thus, consider the case in which the preamble (Pb)
alone is received as an interval containing no informa-
tion in the received frame.

20          The period of about 6 symbols is consumed
until the amplitude of the input signal of the
demodulation circuit 112 converges after the control
signal g is preset (time point 403 in Fig. 12F), and
about 15 symbols is additionally required for the high-
25  speed sync process.  In the frame of the sync burst
shown in Fig. 4, the preamble (Pb) period is 44 symbols
(88 bits).  Thus, the time constant of the short
interval average value is required to be smaller than

the 23 symbols (44 - 6 - 15). In other words, the time sufficient for the short interval average value to converge is required to be smaller than the 23 symbols.

As already described, the RSSI signal
5 contains the amplitude component due to the modulation, and the RSSI signal level changes depending on the information transmitted. In the case where the AGC operation is performed in accordance with the long interval average value $r_L$ of the RSSI signal, the time
10 constant of the long interval average value $r_L$ (the time length $t_L$ for which the average value is determined) is required to be at least several tens of symbols in order to prevent the suppression due to the modulation.

Thus, the time length from immediately after
15 the start of signal reception to the time point when the difference value $\Delta r$ of Fig. 12E reaches the threshold value $\Delta r_{th}$ (time point 402 in Fig. 12E), plus the additional lapse of time $t_1$, is set to a sufficient time length $t_s$ ($t_s$ is smaller than the time from
20 immediately after start of signal reception to time point 402, plus $t_1$) for the convergence of the short interval average value $r_s$. Also, the time length from immediately after start of signal reception to the time point 403 and additional lapse of the time $t_2$, on the
25 other hand, is set to a time length $t_L$ ($t_L$ is shorter than the time from immediately after start of signal reception to the time point 402, plus $t_1$ and $t_2$) suffi-cient for the convergence of the long interval average

value $r_L$. The time before the difference value $\Delta r$ in Fig. 12E reaches the threshold value $\Delta r_{th}$ is about one symbol or two. In the case where the time constant of the short interval average is set to six symbols and

5  the time constant of the long interval average is set to 30 symbols, for example, the time $t_1$ is set to 5 symbols and the time $t_2$ to 24 symbols.

As described above, according to this embodiment, the difference value $\Delta r$ (= $r - r_L$) between the

10  instantaneous value of the RSSI signal and the long interval average value $r_L$ is compared with the threshold value $\Delta r_{th}$. In this way, the rise of the received signal can be detected, so that even a sharp rise of the received signal level can be followed by the AGC

15  operation.

In the embodiment described above, at the rise time of the received signal, the RSSI signal is calculated with a time constant of about several symbols to calculate the short interval average value,

20  and after the short interval average is settled, the control signal g is preset by the short interval average value. According to this invention, however, the terminal b of the switch 119 may be connected directly to the A/D converter 104 without using the

25  short interval average calculation circuit 116. In this case, the switching control unit 118 turns the switch 119 from terminal a to terminal b when the difference value $\Delta r$ reaches the threshold value $\Delta r_{th}$

(i.e. when the rise is detected), and presets the control signal g with the instantaneous value r of the RSSI signal, immediately followed by switching from terminal a to terminal c. Also, upon lapse of the time

5  $t_1+t_2$ after presetting the control signal g, the connection of the terminal d of the switch 119 is turned from terminal c to terminal a, and the AGC operation is performed in accordance with the long interval average value $r_L$ of the RSSI signal.

10      Also, in the determining operation (2) of the embodiment described above, the switch 119 has the terminal c to which no signal is applied, and by connecting the terminals c and d, the application of the input signal is prevented. As an alternative, any

15  means can of course be employed obviously in which the switch 119 is disconnected by the signal from the switching control unit 118. As still another alternative, in the determining operation (2), the immediately preceding gain set for the amplifier 102 may be main-

20  tained by preventing, by disconnection, for example, the control signal g from being applied to the amplifier 102 from the gain control unit 110.

Also, in the embodiment of Fig. 9, the long interval average calculation circuit 115, the short

25  interval average calculation circuit 116, the adder 117, the switching control unit 118, the switch 119 and the gain control unit 110 may be processed by a microcomputer such as a DSP (digital signal processor).

Fig. 13 is a block diagram showing such a configuration of the AGC circuit according to another embodiment of the invention. The functions of the component elements 115 to 119 in Fig. 9 are implemented, for example, by a

5 DSP 200. The processing operation of the DSP 200 will be explained with reference to the flowchart of Fig. 14.

First, in step 140, the long interval average value $r_{Li}$ and the short interval average value $r_{si}$ corre-

10 sponding to the latest instantaneous value ri input from the A/D converter 104 are determined. Then, the difference value $\Delta$ri (= ri - $r_{Li}$) between the instantaneous value ri and the long interval average value $r_{Li}$ is calculated (step 142) thereby to determine whether

15 the difference value $\Delta$ri has exceeded a predetermined threshold value $\Delta r_{th}$ or not (step 144). In the case where the difference value $\Delta$ri has exceeded a predetermined threshold value $\Delta r_{th}$, the process proceeds to step 150, and otherwise the process is passed to step 146.

20 In step 146, the value of the control signal g is set to a value based on the latest long interval average $r_{Li}$, so that the value i is updated by 1 in step 148, followed by returning to step 140. In step 150, the value of the control signal g is maintained at a value

25 based on the latest long interval average $r_{Li}$ until the lapse of a predetermined time $t_1$ after the difference value $\Delta$ri has exceeded the threshold value $\Delta r_{th}$. Then, in step 152, upon the lapse of the predetermined time

$t_1$, the value of the control signal g is preset and held to a value based on the latest short interval average value $r_{si}$ upon the lapse of the predetermined time $t_1$. Then, in step 154, upon the lapse of the predetermined

5   time $t_1$ and the further lapse of the predetermined time $t_2$, the control signal g is set to a value based on the latest long interval $r_{Li}$.  After that, the process is returned to step 140.

In the embodiment of Fig. 9, only the switch-

10   ing control unit 118 may be processed by a micro-computer such as a DSP.

It will thus be understood from the foregoing description that according to this invention, the AGC operation is rapidly pulled in at the time of rise of

15   the received signal level by detecting the received signal level.  Also, as long as the received signal is continuously received, the AGC operation is performed at low speed with the long interval average of the RSSI signal in order to prevent the suppression of the

20   amplitude component of the modulated wave.  As a result, a proper AGC method can be selected in accord-ance with the receiving conditions.